The Electron Relativistic Heavy Ion Collider: Designing a Detector Using Simulated e+p Data Analysis

William M. Foreman[1], Anders Kirleis[1], Matthew Lamont[2], and Elke-Caroline Aschenauer[2]
[1] SUNY at Stony Brook, Stony Brook NY 11790 & [2]Physics Department, Brookhaven National Laboratory, Upton, NY 11973
August 2009

Abstract

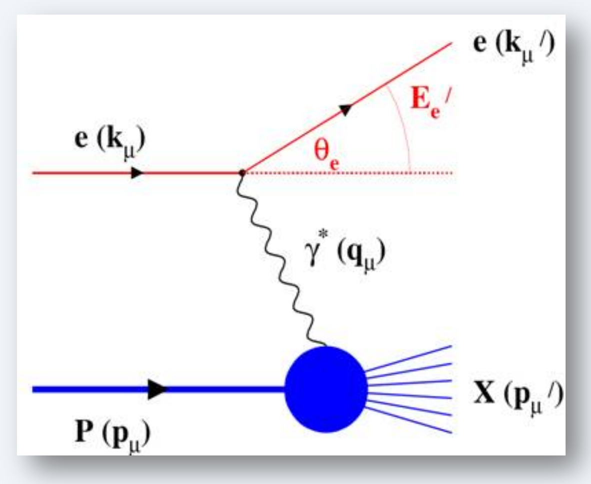
Deep inelastic scattering (DIS) and diffractive scattering are used to probe the internal structure of hadrons in accelerator physics. During the design of experiments, such high-energy processes are simulated using Monte-Carlo (MC) event generators such as RAPGAP which use random numbers to rapidly replicate the complex interactions in such collisions.

New information from these simulations is needed to design a detector for the proposed Electron Relativistic Heavy Ion Collider (eRHIC) at Brookhaven National Laboratory (BNL), set to be completed by 2020. Millions of electron-proton (e+p) collision data events were produced by RAPGAP, simulating both DIS and diffractive collisions at energies of 4 on 100, 4 on 250, 10 on 100, 10 on 200, 10 on 250, and 20 on 250 GeV, after which C++ code using intrinsic ROOT functions was edited and run to read the data, calculate kinematic variables, and organize the results into a data tree. Additional ROOT codes were modified to produce customized plots to visually represent the massive amounts of data and to help understand the realistic quality of the simulator. Over time these codes can be easily modified to plot information as needed, and can be applied to newly produced MC generator data simulating collisions between electrons and heavy ions.

Significant differences were found between DIS and diffractive physics in the distribution of momentum and scattering angle for electrons, pions, and kaons. From these results comes a better understanding of these intricate processes, and by knowing where particles go after a collision along with the energy they carry, estimates of exact positions and spatial dimensions of various particle-sensitive devices around the collision point can be better determined.

Such information is vital in designing an eRHIC detector at BNL that will most effectively collect useful and groundbreaking data in future experiments.

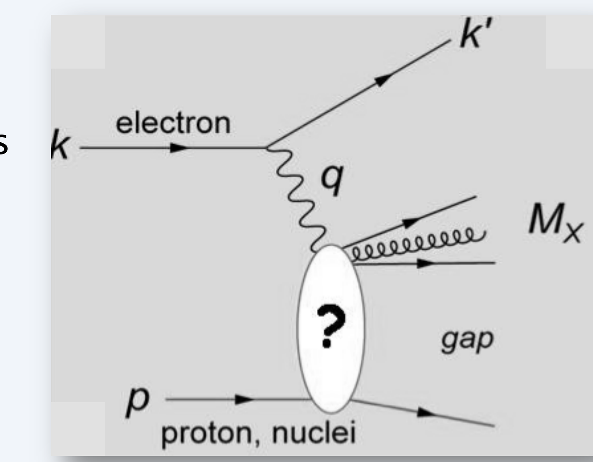
Deep Inelastic Scattering (DIS)

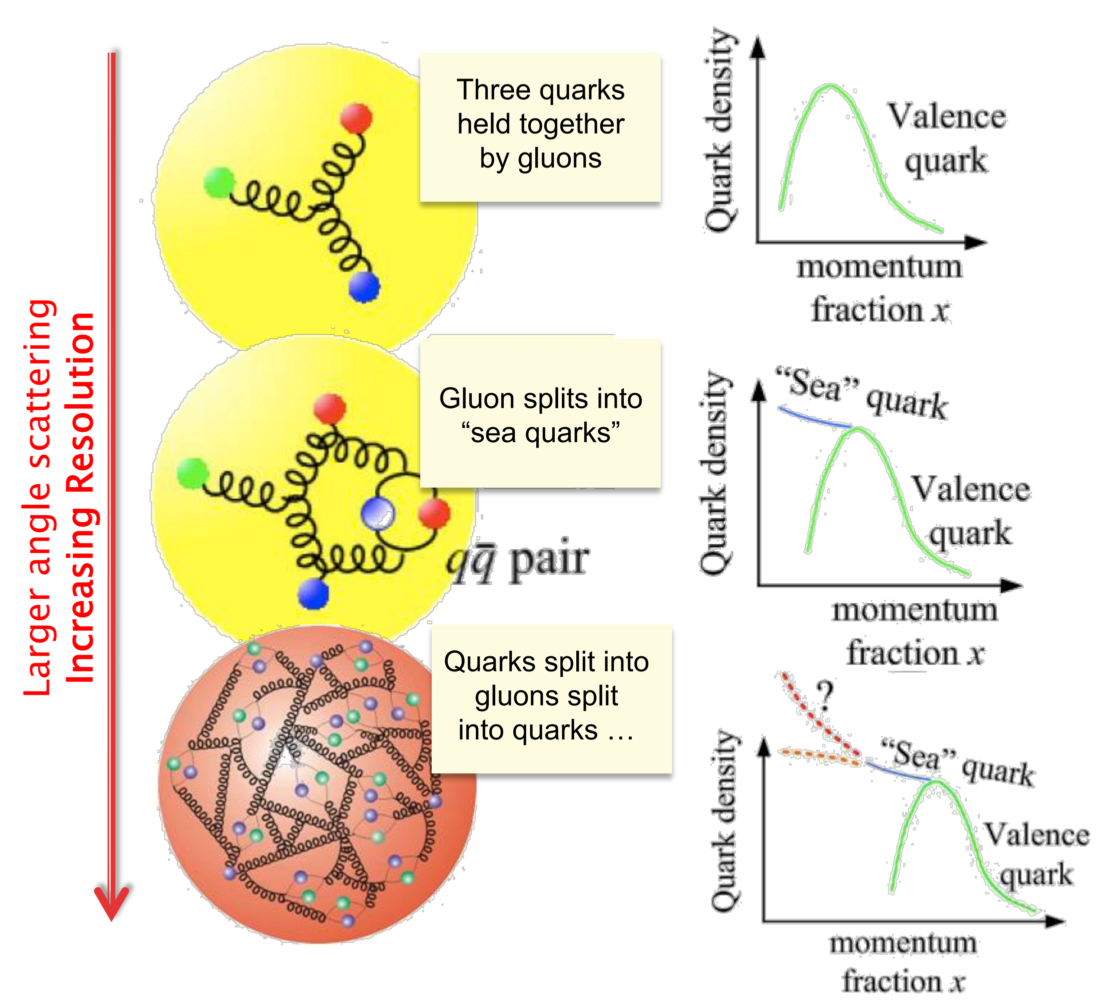


A high-energy electron (e) interacts with a parton (quark or gluon) through an exchange virtual photon (γ). E' is the scattered electron and X is the resulting particle shower.

Diffractive Scattering

In diffractive events, the proton (p) remains intact and there is typically a "rapidity gap" in which no particles are radiated from the collision.

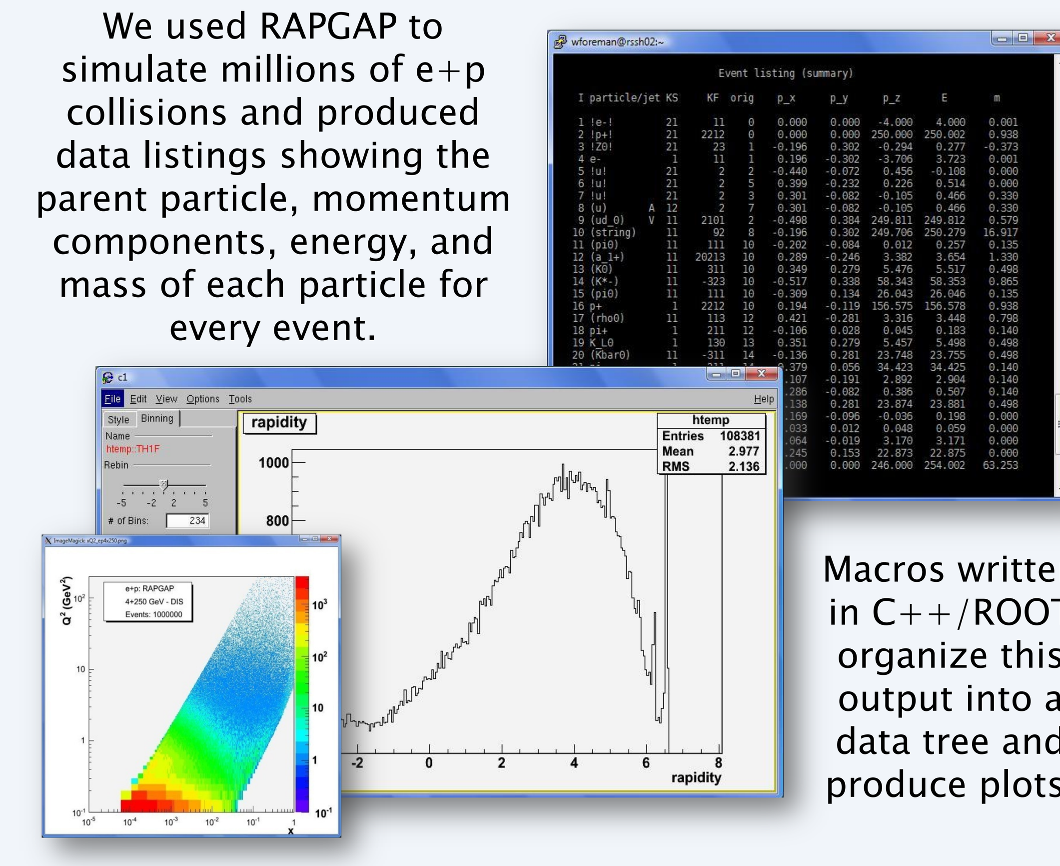




At larger energies we "see" the proton in greater detail and can study the behavior of quarks in the low-x regime.

Data Simulation

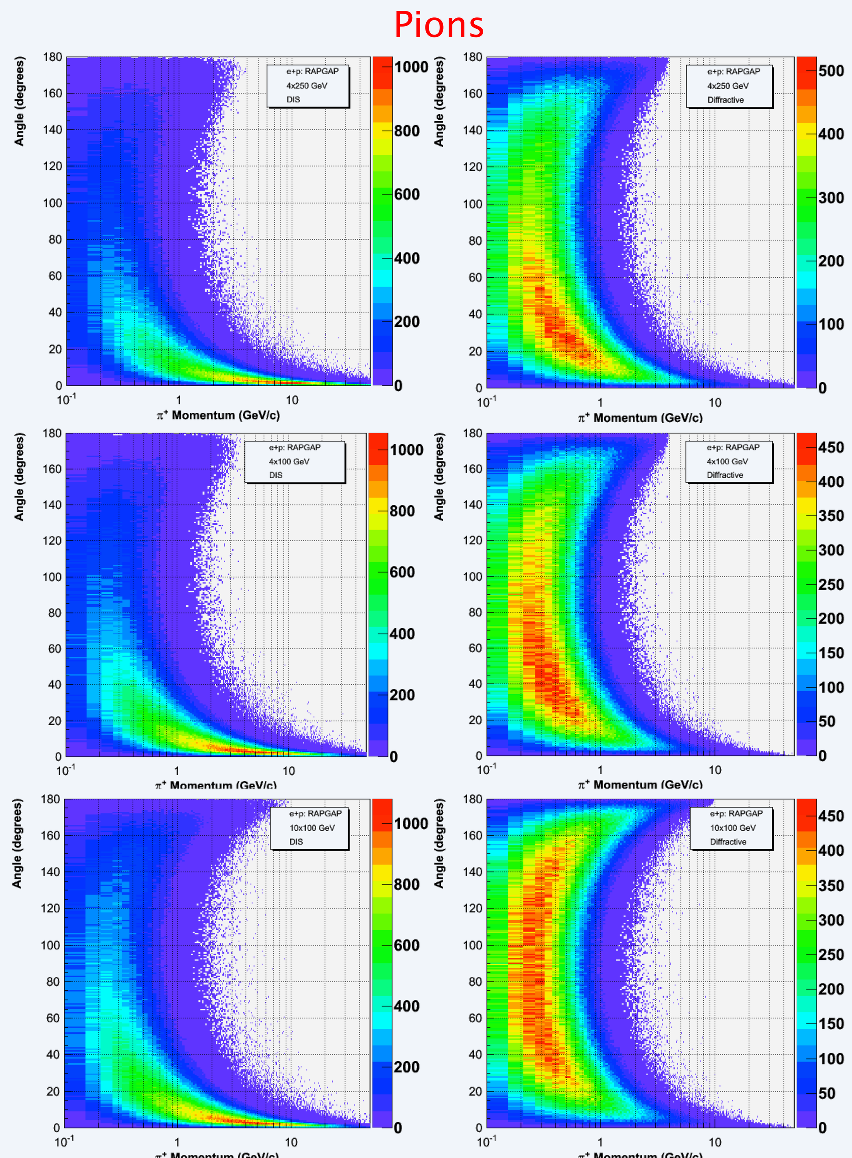
We used RAPGAP to simulate millions of e+p collisions and produced data listings showing the parent particle, momentum components, energy, and mass of each particle for every event.



Macros written in C++/ROOT organize this output into a data tree and produce plots.

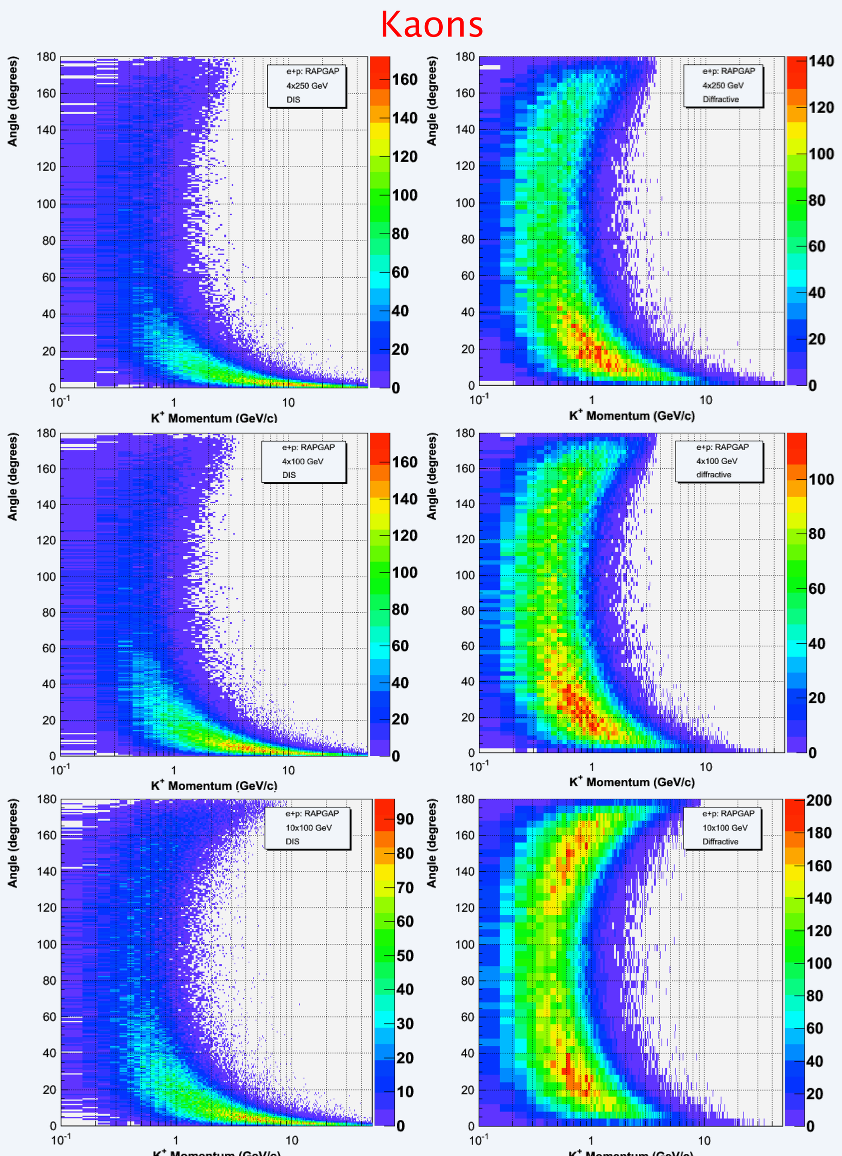
Results for Pi+ & K+ Momentum vs. Angle Distributions

Pions



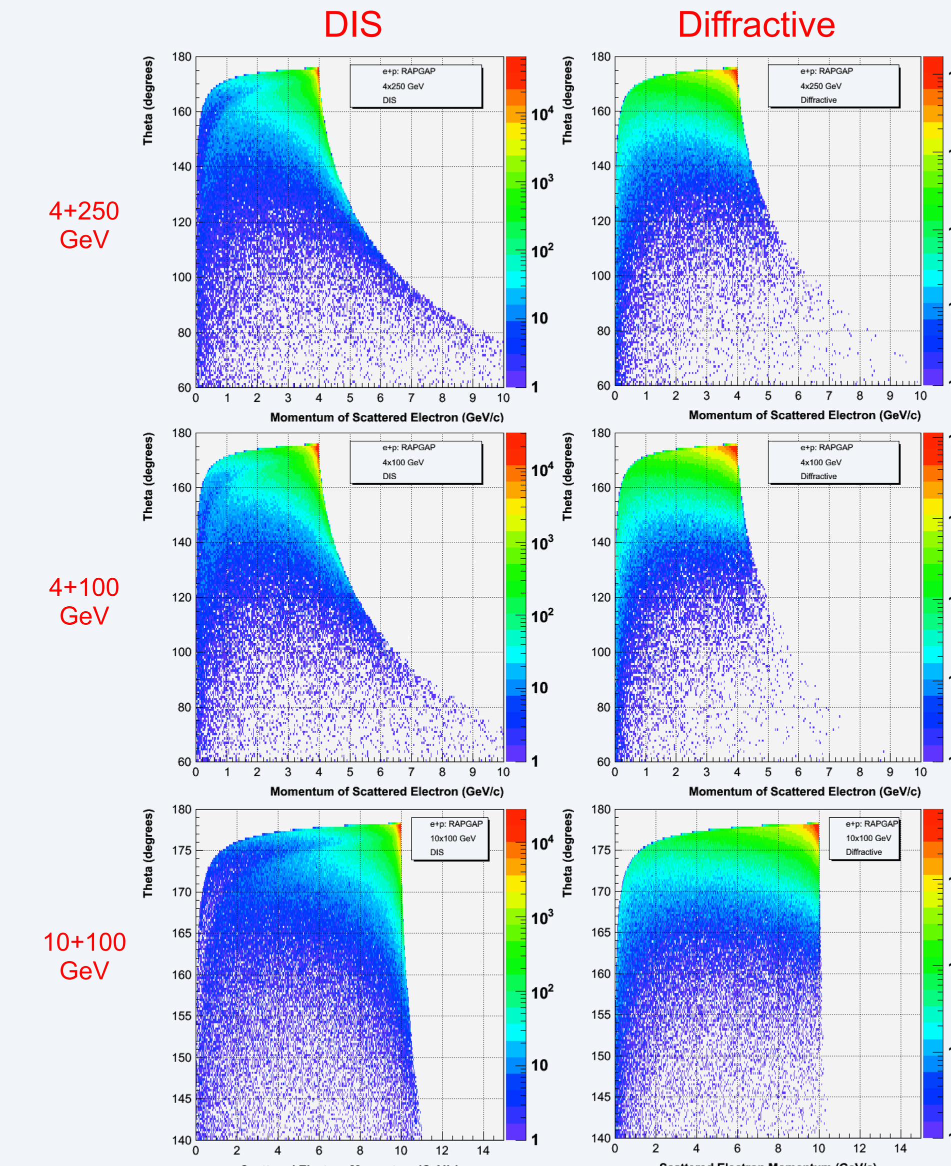
- Diffractive events produce a larger range in angle compared to DIS
- Due to their larger mass, kaons are mainly scattered at smaller angles compared to pions
- For diffractive events, 10+100 GeV, pions show a smooth, symmetric distribution between 20 and 160 degrees while kaons are projected in forward/backward jets

Kaons



Results for E' Momentum vs. Theta Distributions

DIS | Diffractive



- Electrons in DIS events are more likely to scatter at a larger angle relative to initial lepton beam direction (180 degrees) and with larger momentum
- Diffractive events show a wider range in the momentum of the scattered lepton while DIS events are more concentrated at a specific value

Conclusion

From these results we obtained a better idea of the acceptance range the eRHIC detector will need to cover to best sense pions, kaons, and scattered electrons that radiate from high-energy e+p collisions.

The design of the Electron Relativistic Heavy Ion Collider is an ongoing effort and further simulations and studies are needed to determine the exact parameters for the layout and geometry of the detector.

Acknowledgements

A special 'thank you' to those who provided much-appreciated guidance and who made this work possible!

Matthew Lamont
Elke-Caroline Aschenauer
Abhay Deshpande
Michael Savastio
EIC Task Force & BNL Physics Department
Samuel Aronson and Steven Vigdor
Mel Morris and the OEP Staff

BROOKHAVEN NATIONAL LABORATORY
STATE UNIVERSITY OF NEW YORK STONY BROOK DEPARTMENT OF PHYSICS & ASTRONOMY
Office of Science U.S. DEPARTMENT OF ENERGY
SULI